Summer Cloud Modification

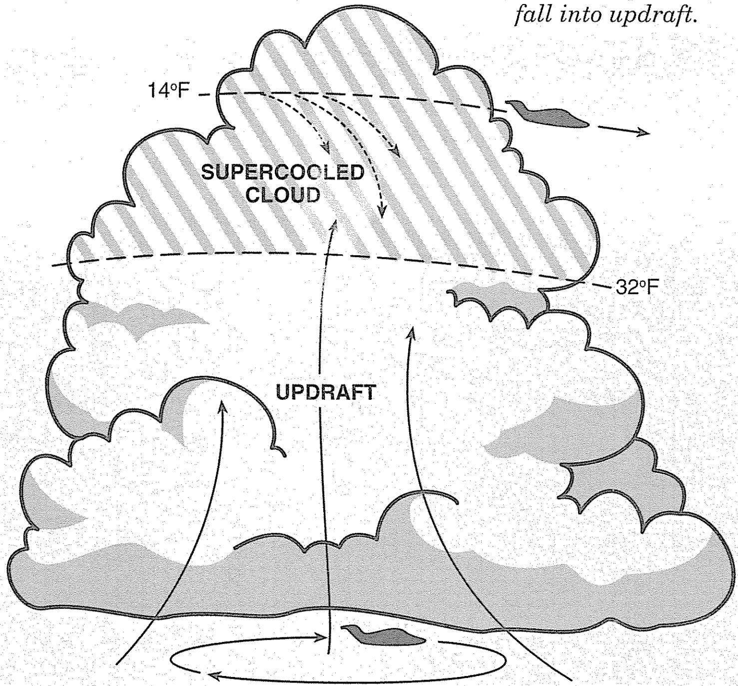
weatherguide

supercooled water

When the top of a growing cumulus cloud cools to less than 32°F, cloud droplets *do not immediately freeze*, but instead become **supercooled**. In spring and summer clouds over the northern High Plains, ice often does not form until cloud tops cool to temperatures of 5°F or colder. Then, tiny windblown dust and soil particles called **ice nuclei** serve as crystalline skeletons upon which droplets freeze and snowflakes form. If ice does not develop in the short-lived summertime clouds, the cloud droplets soon mix with the drier air outside the cloud and evaporate.

When the high, supercooled, cumulus cloud tops do not speedily spawn ice, raindrops can only form through the collision of the minuscule cloud droplets. This process, called **coalescence**, takes a long time to get started because the cloud droplets are so small (diameter about .0005 inch) that they swirl about in the air currents, and do not readily collide. It takes nearly a million cloud droplets to form a single average-sized raindrop!

On-Top Seeding: *nuclei or dry ice released directly in the supercooled cloud; flares or pellets fall into updraft.*

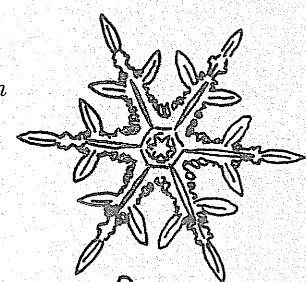


Cloud-Base Seeding: *nuclei from silver iodide burned in flares or solution released in updraft.*

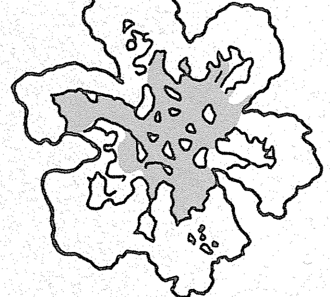
a nudge in the right direction

When nature is reluctant to produce ice in supercooled clouds, it is possible to lend a hand by providing the ice nuclei that nature is lacking. This is commonly known as **cloud seeding**. Clouds can be "seeded" with a variety of ice-inducing agents. The most common are silver iodide and dry ice. When silver iodide is used, small amounts (an ounce or two) are burned in flares or solution in the cloud top or in the updrafts at the cloud base. If dry ice is used, marble-sized pellets are dropped into the growing cloud from above. Rapid development of large numbers of small ice crystals soon follows.

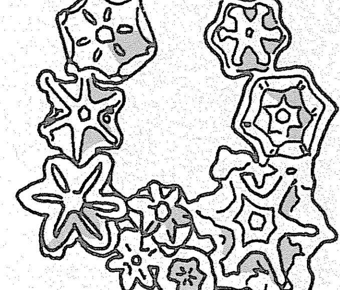
Once ice particles form, they continue to grow by **deposition**, **riming**, and **aggregation**. Deposition is the process that generates



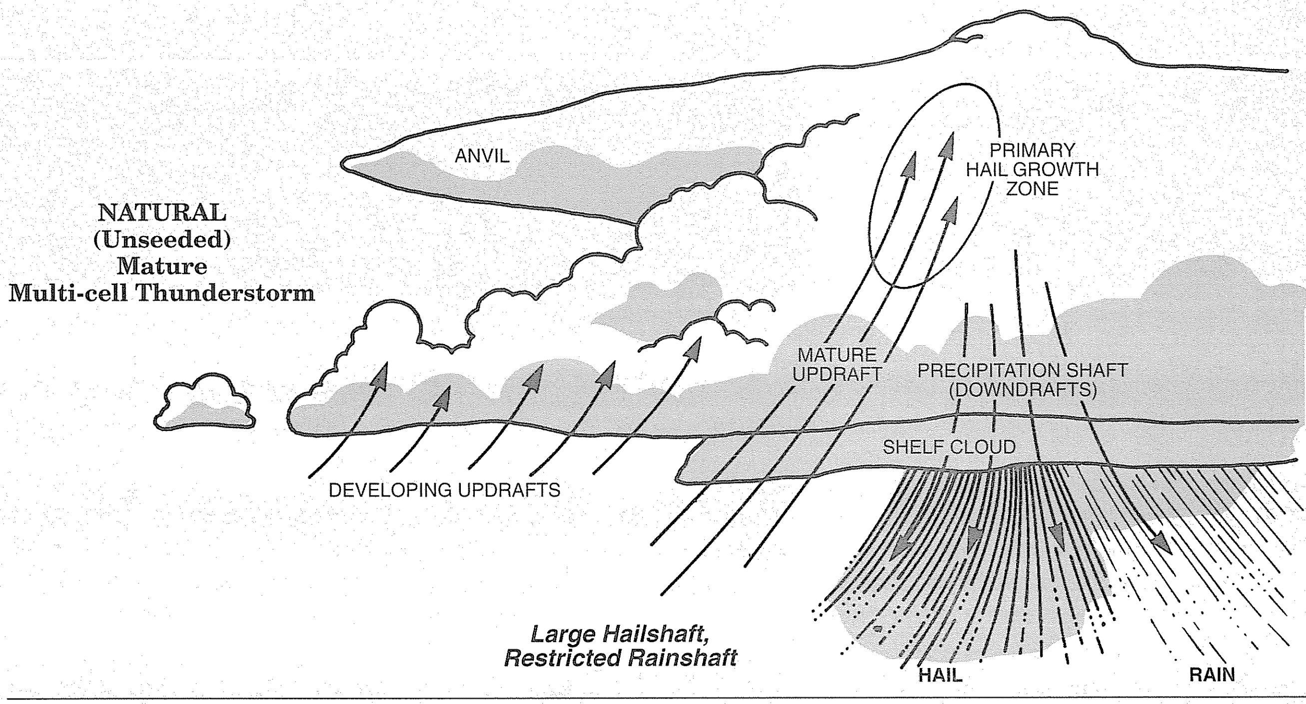
Deposition: *Water Vapor is deposited in crystalline form, making ice without first condensing.*



Riming: *Supercooled cloud droplets freeze instantly when they coolide with existing ice particles, glazing them.*



Aggregation: *Ice crystals collide and stick together, building snowflakes.*



delicate snowflakes, and is the result of water vapor in the air being "deposited" directly on existing ice particles. Riming occurs when ice particles bump into supercooled droplets, which freeze instantly to the ice. Aggregation occurs when ice crystals get tangled with each other. Each of these processes quickly builds larger ice particles, and all three may be working in the same cloud at the same time.

natural vigor

Heat is released whenever condensation, freezing (riming), or deposition takes place. This energy warms the cloud, strengthening the updraft. The updraft in turn pulls in more moist air from below, helping the cloud grow taller and last longer. In the course of a typical thunderstorm's lifetime, energy equivalent to that of an atomic bomb is normally released, so it is not surprising that violent weather often results.

Clouds growing on the flank of a thunderstorm, called **feeder clouds**, often develop large amounts of supercooled water. These supercooled droplets may be swept into the vigorous hail-producing updraft of the main storm as the feeder cloud grows and merges with it. Once in the mature updraft, the supercooled liquid water feeds hailstone growth. Because freezing releases heat, energy is thus added to the updraft, helping sustain the very powerful upward air currents which hold growing hail aloft.

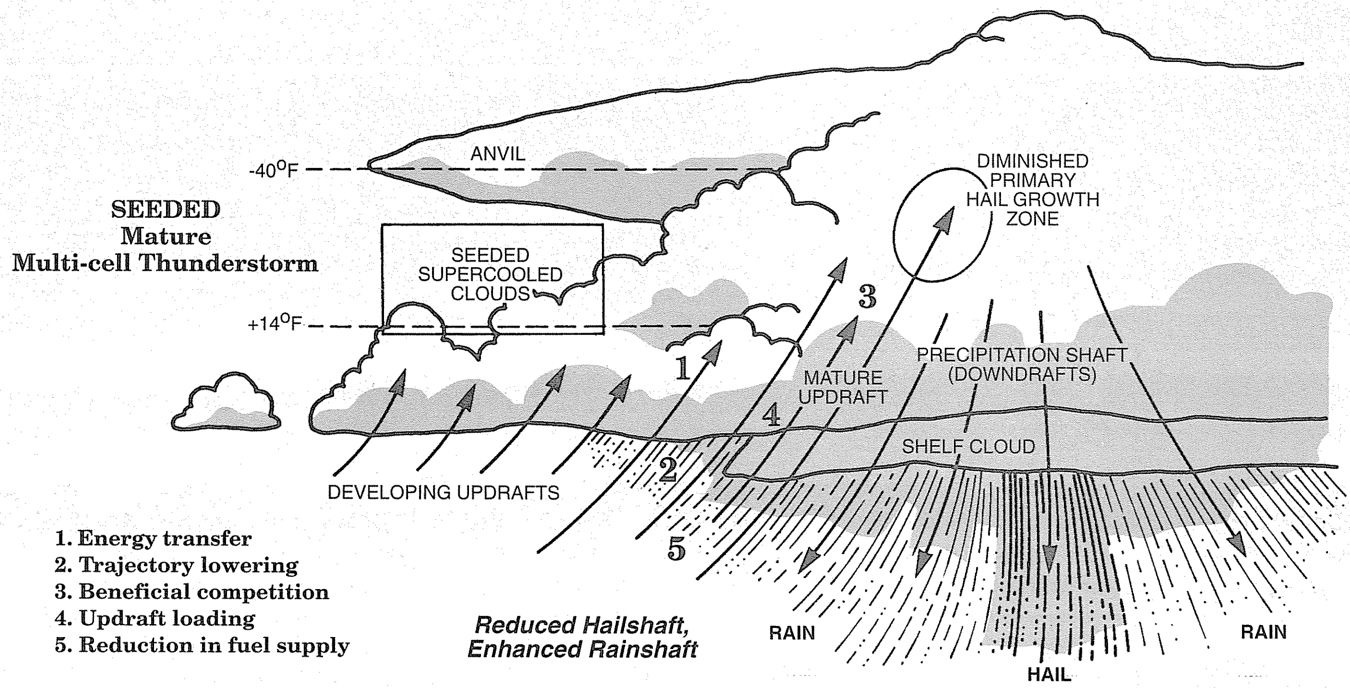
the impacts of seeding

Timely seeding of the feeder clouds can lessen the storm's severity, while increasing overall rainfall. This is accomplished in a variety of ways, effectively spreading the energy released by the storm over a slightly larger area.

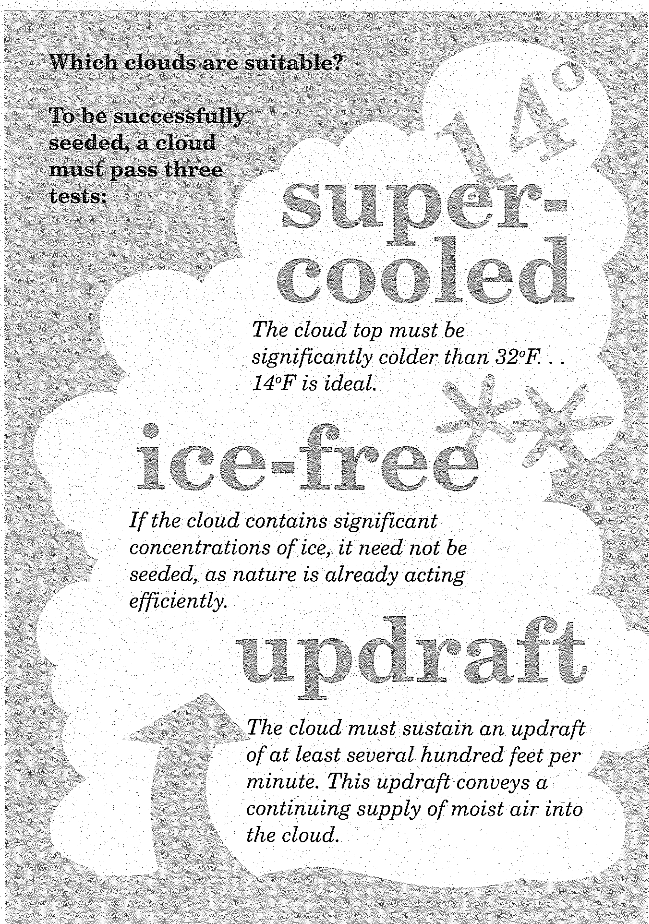
1. Energy transfer. If the feeder cloud is seeded, slightly more energy (heat) is released when ice forms earlier, in the feeder cloud instead of in the main updraft. This makes a gentle updraft a bit stronger, rather than feeding the hail-producing updraft of the main storm.

2. Trajectory lowering. The seeding of growing feeder clouds will cause cloud particles to grow large enough to fall from the gentle updrafts of the feeder cloud and melt into rain, *before* the cloud merges with the mature updraft and they get carried far aloft where most hail develops.

3. Beneficial competition. If large numbers of the small ice particles resulting from seeding enter the updraft, they compete with each other for the available supercooled liquid water that would grow hailstones, rapidly using it up. When they do fall out, they are significantly smaller, and have a much better chance of melting before reaching the ground.



4. Updraft loading. When development of precipitation particles is accelerated as described in 2. above, particles remaining in the feeder cloud when cloud merger occurs are often larger and more numerous than would naturally be the case. The updraft is thus burdened and slowed by the additional weight it must support, and is less capable of growing large hail.



5. Reduction in fuel supply. The "fuel" that drives thunderstorms is water vapor, commonly known as humidity. The energy released as the vapor condenses and then freezes warms the air within the updraft, which gains strength, pulling in even more moist air "fuel". It is not possible to "turn off" the moisture supply, but the earlier rain development that results from seeding feeder clouds will produce a precipitation shaft in an area previously rain-free. The rainshaft partially restricts the main updraft's access to the moist air that generally lies to the south and east of the main updraft.

which clouds are suitable?

Before a cloud is seeded, it must pass three tests. The cloud top must be colder than about 23°F, as warmer clouds won't develop much ice, even though they may be slightly supercooled. The cloud must have a steady updraft, to provide a continuing supply of the moist air that allows the ice particles to keep growing. Finally, the cloud must *not* have much natural ice. If the cloud has already developed ice, it need not be seeded, as nature is already being efficient. Thus, the cloud must be **cold**, **ice-free**, and have an **updraft**.

what can be expected?

A well-run, adequately funded seeding operation employing aircraft for a seeding and weather radar for guidance can result in significantly less hail damage (30 to 60 percent reduction), and limited but very valuable increases in precipitation (on the order of 10 to 15 percent).

A series of independent evaluations of the North Dakota Cloud Modification Project (NDCMP) have all shown positive impacts. The most recent, published in the American Meteorological Society's *Journal of Applied Meteorology* in May 1997, shows a 45 percent reduction in crop-hail damage. The program costs on the order of ten cents per acre.

Weather modification by cloud seeding is increasingly used as a water management and hazard mitigation tool in the U.S. and abroad. More than half of the states in the western U.S. now regularly apply the technology.

Information about current American operations can be obtained from the National Oceanic and Atmospheric Administration, 1325 East-West Highway, Silver Spring, MD 20910.

when should cloud seeding be considered?

Any part of the northern High Plains suffering significant hail damage on a regular basis would likely benefit significantly from hail suppression operations. In addition to the direct savings realized, long term programs which establish lower hail risks in target areas will also enjoy lower hail insurance premiums.

Additional growing-season rainfall will prove very beneficial to any locale short of moisture, especially semi-arid regions suffering chronic shortages.

Longer-term applications of cloud seeding technology may lessen the impact of droughts by creating greater soil moisture reserves prior to the onset of drought conditions, and may accelerate recovery by increasing the rainfall when weather patterns return to normal.

Because cloud seeding simply enhances the natural efficiency of clouds, it may be of limited use during extended periods of drought, when suitable clouds are in short supply.

additional reading

Hail: A Review of Hail Science and Hail Suppression, edited by G.B. Foote and C.A. Knight. Meteorological Monographs, Volume 16, American Meteorological Society, Boston, 1977.

Weather Modification by Cloud Seeding, by A.S. Dennis. Academic Press, New York, NY, 1980. International Geophysics Series, Vol. 24.

Meeting of Experts to Review the Present Status of Hail Suppression, R. List, Editor, World Meteorological Organization, Geneva, Switzerland, 1996. WMO/TD 764.

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